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# ORIGIN OF CERTAIN FEATURES OF COAL BASINS.

WHILE the general theory of the formation of coal has long been worked out and accepted, it cannot be said that the details of the process are as yet altogether understood. Numerous puzzling phenomena are constantly encountered in all coal regions. In some regards Iowa is a particularly good field in which to work out certain of these points. The coal seams here are relatively thin and lie near the surface. The region has not been disturbed by mountain-making forces. The seams, with one or two exceptions, are not of great areal extent as is common in certain other fields, but are usually quite limited. Indeed it is frequently possible to find the whole of a seam in a single exposure and to be able to trace it readily from one limit to another. Thus the coal beds are reduced to the lowest terms and so become miniature representations of larger coal basins. They serve as models and present opportunities for investigation of certain phases of their structure which in larger basins have been obscured.

In the following paper an attempt is made to explain a few of the different questions which arise in the study of coal beds. The observations were made on the beds of the Iowa-Missouri field alone, and the explanation is only offered as true of certain of these beds. Whether it is of value in other fields or not cannot be told; to workers elsewhere it may perhaps be of suggestive interest.

There is probably no peculiarity of the coal seams of this region which is more constant than what has been called their basin character. In any individual bed the coal is not everywhere of the same thickness; neither does it all lie at the same level. These two variations have usually a constant relation to each other, it being commonly true that the thinner coal is found at the higher points in the seam and the thicker lies in the lower intermediate regions. The exceptions to this rule are rare and are usually found either where the rise is slight and covers a small area or where the coal is of an impure or bony character. In all the greater differences the coal thins towards the rise.

These lower lying portions of the coal beds are usually called by the miners "swamp coal" or "basin coal" and it is in these swamps or basins that the thicker and more productive portion of the beds lie. In many cases these basins have been traced considerable distances, maintaining the general character of a trough with coal thick at the center and thinning on each side. The area they cover is usually quite irregular. In a few cases the bed underlies a broad circular area thinning quite regularly as it rises in all directions from the center. More usually the length in one direction is much the greater, instances being known where areas of workable coal only about 100 yards wide have been traced nearly a mile. They do not run in direct lines but curve often in an intricate and irregular manner. They are not confined to any one locality but are found in such widely scattered regions as Scott, Keokuk, Jasper, Marion and Lucas counties. Indeed they are present in nearly every region in the state in which coal is mined and are largely sought for by operators. They seem to be more abundant and more irregular in character in the lower horizons. The general character of such a coal basin is represented in Fig. 1, a composite section. On the one side the coal rises twenty feet in a distance of 320, thinning from six to four feet. On the other hand it rises sixty feet in 400 and thins from six to two feet. These two instances are taken from a large number which might be given. The rise of sixty feet is rather unusual, the variation being more frequently from twenty to forty feet. In mining, neither the total variation in elevation nor in the thickness of the seam is usually learned, since so soon as the coal becomes too thin for profitable mining it is rarely traced farther.

A number of these cases have been examined and the relations between the amount of rise and the decrease in thickness determined. The cases examined yield a series of ratios varying from 1 : 6 to 1 : 30. The greater number fall between 1 : 10 and 1 : 16, so that the average may be taken as lying between these figures.

In connection with these basins usually a considerable number of small slips or true faults are found. These rarely have a great throw though in a number of instances they parallel each other, forming a step fault with an aggregate throw of considerable extent.

Frequently these slips parallel the basins. In some cases cracks or veins filled with calcite also run in a parallel direction. Another peculiarity often observed is that the slips do not run clear through the coal; more usually they come in from the top but disappear before reaching the bottom. This, however, is not confined to the most pronounced basins, but it is also frequently found in those coals which have a true bedded character, such as the Mystic coal.

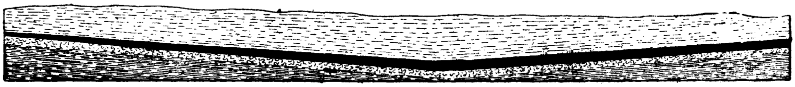

Fig. 1.

In discussing the origin of these basins it will be convenient to consider separately the lines now formed by the top and the bottom of the coal. Considering first the latter the resemblance to the cross section of a valley is at once seen to be striking. This is well brought out in the figure of the Vanderberg mine, a small slope about three miles south of Pella on the Des Moines River. Fig. 2 represents the conditions at this point. The Saint Louis limestone here forms an almost continuous outcrop some distance along the river. It rises to a height of thirty or forty feet. At the place in question the coal lies undisturbed at a level at least fifteen feet below two contiguous limestone outcrops only a few feet distant. It is evident that this coal was formed in a depression in the limestone, and the relations exhibited on the ground show just as clearly that this was a basin of erosion. There is no evidence of disturbance or faulting. The limestone ledges of the two opposite sides of the basin may be as directly correlated as those on opposite sides of a modern stream. In working the coal in this mine, which is merely a small country bank, it has been found that the coal dips toward the present river. Thus it seems that this vein was laid down in a small gully or ravine opening out into some larger basin, the margin of which was located approximately along the present course of the Des Moines.

In these and other cases it is at once seen that the lower line is the cross section of a previously existing ravine. There is no reason to doubt that a similar statement would hold in a great number of the remaining cases. In all places where there has been an opportunity to examine the underlying rocks this has been found to be true. In a majority of the other cases known the coal horizon lies undoubtedly above an unconformity of erosion, and the underlying rocks are known to have suffered erosion sufficient to account for just such outlines. Not all, however, are known to be so located. In a few instances similar basins are found in seams which so far as known do not overly any unconformity. In the veins which lie high up in the coal measures the coal often has a rolling or undulatory character, differences of twenty to twenty-five feet in elevation being not uncommon. In such cases there is not always a constant rule as to the thinning of the coal over the higher points. It is only as the basins are traced out to their limits that the rule appears to hold. These minor changes can readily be accounted for by the secondary changes induced by the consolidation of the

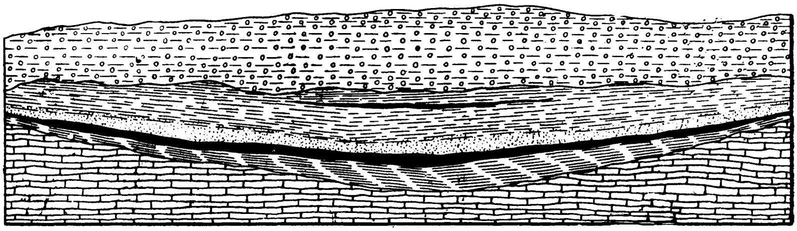

FIG. 2.

immediately underlying strata. In other instances, as for example the "second seam" in the Eureka mine at Des Moines, the usual rule holds true.

If we conceive the coal seam at the time of its formation, we would have essentially what may be seen in any modern peat swamp. The loose vegetal matter lies under the water completely covering the irregularities of the bottom and rising to a practically uniform level a short distance below the surface of the water. In the process of change by which the vegetal matter is transformed to coal it loses a considerable percentage of gas and water so that the relative percentage of carbon increases in regular order from wood to anthracite.

Bischof in studying these changes calculated the total loss which takes place in the change of wood into coal. He assumed that the change had taken place by three processes:

1. By the separation of carbonic acid and carburetted hydrogen.
2. By the separation of carbonic acid from the elements of wood, and by oxidation of hydrogen by external oxygen.
3. By the separation of carbonic acid and water from among the elements of wood.

Under these three assumptions the wood lost as follows: (1) 78 per cent.; (2) 58.3 per cent.; (3) 45.5 per cent.

It is readily seen that with so great a loss of material there must be a corresponding decrease in volume. As the gases escaped, a process yet in operation in the deeper mines of other regions, the strata settled. The amount of this settling may be arrived at as follows.

In the coal basin figured above it will be seen that at one point the floor of the coal bed is sixty feet above the lower portion adjoining. At the time of the deposition of the vegetal matter both these points were covered to a considerable depth, the loosely compacted material rising probably to an even level. It is evident that at that time there was sixty feet of material less over the high than the low point. The whole mass became so deeply buried that the pressure of the overlying beds may be assumed to have been equal at both points. This assumption is especially safe since the two points are but a short distance apart. As the matter yielded to this pressure, it decreased in bulk until in the end it assumed the thickness now seen. The fact that the character of the coal at both points is similar confirms the assumption that the conditions and pressure at both points have been the same. It thus becomes evident that the original difference of sixty feet in the thickness of the vegetal matter ultimately gives a difference of four feet in the thickness of the coal; or that each foot of coal now present occupies one-fifteenth the vertical space which it originally filled. This ratio has been calculated for a number of cases in Iowa and is found in a major portion of instances to lie between one to ten and one to fifteen. Thus the rule is reached that in the process of consolidation Iowa coal seems to have been reduced to from one-tenth to one-fifteenth its original bulk. It should be remembered in comparing these estimates with those made in other fields that the Iowa coals have not been subjected to the action of mountain-making forces. There has been no lateral pressure, and the vertical pressure has probably been comparatively slight.

The changes due to this compression would be slight in the beds under the coal. To the degree in which they were soft and unconsolidated they would themselves be amenable to the same pressure. As a matter of fact they were only slightly affected. The fire clay immediately under the coal, if thick, frequently shows the greatest changes. It was of course subject to irregularities of deposition and hence varies in thickness. When the strata consolidated the fire clay was more unyielding than the coal so that a greater thickness of fire clay is marked by a "horseback" or ridge pushed into the coal. Changes in the thickness of the coal bed would not greatly affect the underlying strata except to the slight degree in which they may at times have lessened the pressure on the fire clay. The effect of such a decrease would correspond to that now seen in "creeps" which are due to a similar cause.

In the coal bed itself the effects of the settling may be seen in the small slips or faults which are encountered. As the coal became older and less plastic it was able to resist the pressure for a considerable time. Finally the accumulated force would cause it to yield, and this yielding would take the form of a series of slips or of cracks along its edges rather than of a gradual unbroken deflection. Since the lower beds were more largely resistant the faults do not often extend far into them and frequently do not even extend to the bottom of the coal.

In the beds above the coal the effects of this action must be large. The shales which lie immediately over a coal seam are frequently quite badly faulted. This is usually more evident in bituminous than in argillaceous shale. This is probable due to the fact that just in proportion to the degree with which they are charged with bituminous matter they would themselves undergo the same loss and other changes which occurred in the coal. In general, however, shale accommodates itself readily to pressure. Limestones and sandstones prove more unyielding and break with sharp fault lines into the underlying coal beds.

One of the most important results of these changes and the one which gives them their deepest economic significance is the part which such a change in a coal seam would play in inducing the deposition of overlying seams. Starting with the conception of a coal swamp as a low-lying coastal marsh it will be seen that any irregularity in the surface which makes an inreaching basin will afford better opportunities for the formation of a coal seam since it will give a better—more protected—area for the growth of plant life and will shield the deposit from the incursion of currents. The influence of such preëxisting irregularities is believed to be seen in the coal seams already described, as for instance that at the Vanderberg mine. Now if there be a sufficient cause for the prolonged and gradual subsidence of the area, the ideal conditions for the formation of a coal seam would be present. It must be evident that in the course of such secondary changes in a coal body as has been sketched above there would be, unless sedimentation were active, an area over each coal basin which would become depressed. For a considerable time this area would continue to sink. This action would be very slow and probably long continued. As a rule the strata covering coal seams are shales and are indicative of slow and even deposition. If then a coal basin be formed and coal be deposited in it, that coal in the process of solidification would, provided the general subsidence of the region continued, thus give rise to conditions favorable to formation of a second seam above it. This second or upper seam would repeat to a greater or less extent the irregularities of the first. The inequalities in the thickness of the upper seam would probably not be so great as in the lower seam.

From the above it follows that if in working a coal seam — where the general conditions are the same as in the Iowa field — a marked basin character is found, it is indicative probably of one of two things. Either the coal lies above an unconformity and the irregular character of the coal is the expression of that fact, or it may lie above another coal seam and its irregular distribution may have been conditioned by the equal settling of the lower bed.

How far this may aid in prospecting for coal seams cannot now be said. It must not be forgotten in applying it that there are many beds other than coal which undergo important secondary modifications in thickness. The influence of underground waters in washing out underlying strata and thus producing irregularities in the position of overlying beds may also perhaps need to be taken into account. In at least one instance, however, there is confirmation of the reality of the process sketched above.

In the region around Des Moines there are a number of mines which have at different times worked two seams of coal separated by thirty-five to forty feet of shale. The maps of these mines have usually been very imperfectly kept and levels are only occasionally available. In the Eureka mine the second seam is now being worked. The first is a thin seam which has no value. The third lies about forty feet below the second and has been worked out. In both the second and third seams the basin character is a prominent feature. *It is found in working the second seam that the thicker low-lying coal overlies the areas from which the swamp coal was taken in the third seam.*

The opportunities for thus testing the truth of this theory are, in this field, quite rare since only a very small number of the mines ever work more than one seam.

H. FOSTER BAIN.

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